SubsurfaceTopics

INEEL Subsurface Science Initiative

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In This Issue

Initiative Director
P. Michael Wright, Ph.D.
(208) 526-3315 or
wrigpm@inel.gov

For general information, or to be added to the mailing list, contact:
Deborah Hill
(208) 526-4723
dahill@inel.gov

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INEEL Wins Funding for Array of EMSP Projects

This year, DOE's Office of Science competitively awarded funding to 35 Environmental Management Science Program (EMSP) research projects related to subsurface contamination in the vadose and saturated zone. Researchers at the INEEL will lead seven of these projects and participate in three others led by collaborators at the University of Idaho and Los Alamos National Laboratory.

"This was a great year for our program. We wrote good proposals and the merit of our research ideas was evident to reviewers."

— M. Wright, INEEL Subsurface Science Initiative Director

Each of the projects, ranging from studying new models or modeling concepts to investigating new instruments and remediation techniques, will receive three years of funding. (See page 8 for a brief description of each project.)

"This was a great year for our program," said Subsurface Science Initiative (SSI) Director Michael Wright. "We wrote good proposals and the merit of our research ideas was evident to reviewers. It's also an indication that our research investments are beginning to pay off."

Since the SSI's inception, the INEEL has invested significant discretionary resources in building a stronger subsurface science research capability. This has included $8 million in Laboratory Directed

(INEEL wins continued on page 8)

An INEEL-led Environmental Management Science Program (EMSP) project will use the INEEL's new Geocentrifuge Research Laboratory (above) to develop new experimental approaches for studying coupled flow and reactivity. This research will test the hypothesis that contaminant transport is controlled more by media characteristics than chemistry.

Western Connections

— Seeking Solutions to the Region's Energy and Environmental Challenges

The spirit of cooperation that helped settle the Old West may be the key to resolving the complex energy and environmental problems of the New West. Today, that spirit is embodied in the INEEL's Western Connections program, which draws from the vast resources of the INEEL and its university partners to facilitate collaborations in scientific research and technology development.

DOE's national laboratories are huge assets for solving pressing scientific challenges, but they have been essentially untapped for addressing regional problems in the Intermountain West. Jan Brown, an INEEL advisory scientist and Western Connections lead advocate, discovered one reason for this — a lack of mutual awareness. The INEEL was disconnected from regional issues, and regional agencies and industries were unaware of the Laboratory's research and technology capabilities.

"For years, the INEEL has provided up to forty hours of technical assistance to local and regional governments that approached us for help," said Brown. "But few have been aware of the service or how to take advantage of it. Western Connections is a means to foster these important relationships beyond eastern Idaho and to improve communications across the region."

Brown, well-known in the nonprofit sector for her work forming successful collaborations on Western natural resource issues, took a nontraditional approach to building these new relationships. "We had to understand the issues well before we could identify areas of mutual interest," said Brown. "So, instead of trying to sell or impose our expertise with limited knowledge of the problem or its local context, we conducted a regional 'listening tour.'"

Brown had three objectives for the tour:

1) Identify emerging environmental issues that align with the INEEL's expertise and problem-solving capabilities;
2) Introduce the INEEL's SSI and strengthen INRA partnerships; and
3) Cultivate new relationships and networks among regulators, land managers, industry, non-governmental organizations and the larger scientific community.

> *"Western Connections is a means to foster ... important relationships beyond eastern Idaho and to improve communications across the region."*
>
> *— J. Brown, INEEL advisory scientist and lead advocate for Western Connections*

The Western Connections team visited with scientists from the Montana Bureau of Mines and Geology (inset) during a regional 'listening tour.' The team's goal is to facilitate collaborative relationships among the INEEL and local and regional governments to identify solutions. One complex environmental problem the team learned about is the Berkeley Pit in Butte, Montana, an abandoned open pit copper mine that is filling rapidly with heavily contaminated acidic mine water (large photo).

The Western Connections team and SSI representatives traveled to Alaska, Idaho, Montana, Utah, Washington and Wyoming to meet with representatives from government, industry, academia and nonprofit groups. They focused on identifying regional problems that were beyond the capacity of individual states, universities or the marketplace to resolve alone, and relevant to three major INEEL initiatives — subsurface science, environmental stewardship and energy resources.

> ***"Our challenge is to keep the dialogue open and find ways to work together successfully. It is up to us to demonstrate the INEEL's value to the region."***
>
> *— J. Brown, INEEL advisory scientist and lead advocate for Western Connections*

The tour was highly successful because the team identified a variety of issues ready for national laboratory involvement ranging from contamination resulting from mining operations, to coal bed methane development, to confined animal feeding operations.

The team also identified a potential impediment — the INEEL's reputation in working with others. Though they expected to encounter some skepticism because of the INEEL's own problems with contamination, they heard sister agencies, universities and industry representatives voice concerns about bureaucratic barriers, poor follow-through and other institutional behaviors, which resulted in failed collaborations.

These problems are endemic to large federal agencies, but some of the examples specifically involved the INEEL. "Part of being a good partner is asking for critique and then responding to it," said Harold Blackman, INEEL Assistant Laboratory Director. "Clearly, we have some internal issues to address. Both our actions and our behavior define our reputation."

(Western connections continued on page 11)

Coal-bed methane development in many Western states, such as at this site in Wyoming, has resulted in several common environmental challenges, such as poor quality production water.

Zinc/Cadmium Symposium Held to Address Regional Issues

Recently, a four-day symposium was held in Coeur d'Alene, Idaho, to address mining-related zinc and cadmium contamination — one of the most challenging environmental issues facing the Northwestern states. The metals contamination is a particular concern in the rivers, streams and lakes in Idaho's Coeur d'Alene Basin and downstream where the Spokane River exceeds the State of Washington's water quality standards.

The symposium, organized under the auspices of the INEEL's Western Connections program, included members of the INEEL, Inland Northwest Research Alliance, Coeur d'Alene Tribe, Idaho Department of Environmental Quality, U.S. Environmental Protection Agency, Idaho Water Resources Research Institute and the Office of Idaho Senator Michael Crapo. It offered the participants a collective opportunity to discuss all facets of the issue — their goals, the major technical challenges, state-of-the-art remediation technologies, and all phases of technology development, including theoretical analysis, laboratory experiments, pilot tests and field applications. As a result, smaller focus groups were formed to begin building a consensus research agenda.

> ***"Good science is critical to the future of western environmental policy."***
>
> *— U.S. Senator Mike Crapo*

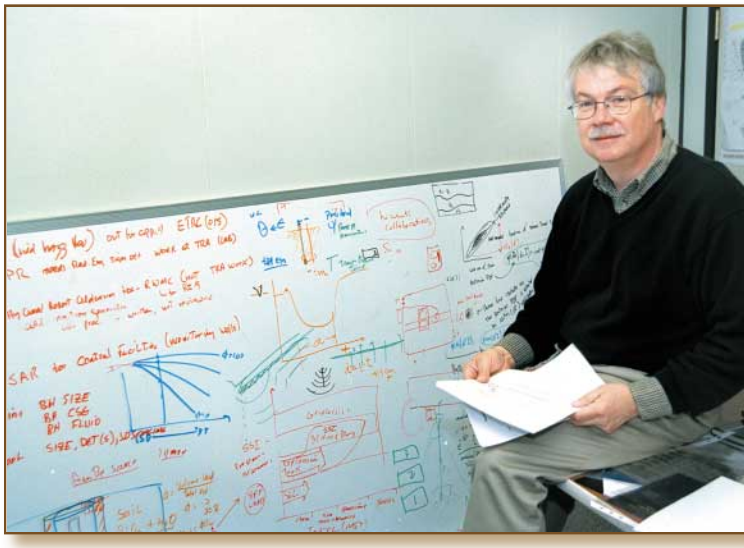
Idaho Senator Mike Crapo has high expectations for the symposium. "Good science is critical to the future of western environmental policy," said Crapo. "That is why I look toward gatherings such as this as the proving grounds for the latest technical knowledge that will move sound policy decisions."

More information about the symposium is available online at http://www.inel.gov/western-connections/

Contact: Paul Wichlacz
(208) 526-1292
plw@inel.gov

Applying Quantitative Techniques to Environmental Geophysics

When it comes to determining quantities of compounds in the subsurface, the oil and gas industry has long had the best techniques. If the INEEL's researchers can selectively adapt the quantitative geophysical methods used by the oil and gas industry to subsurface contamination, DOE could learn more about important contamination problems, such as chlorinated solvents and long-lived radionuclides.



Russel Hertzog, INEEL Subsurface Science Initiative physics discipline lead, is investigating methods of quantifying environmental contamination by applying the experience he gained in instrument development while working in the oil and gas industry.

SSI physics discipline lead Russel Hertzog is working on the problem. While working at Schlumberger Limited, Hertzog pioneered many nuclear-based measurement systems that are now worldwide standards for oil exploration.

Before he launched into research through the SSI, Hertzog examined the DOE's subsurface contamination problems and the available techniques for studying them. "I wanted to see where existing techniques and instruments used in other industries might be refined to meet new problem sets," said Hertzog.

> *"We know some techniques ... can be refined to get quantitative data, but they will need to be adapted for mapping subsurface contamination."*
>
> — R. Hertzog, SSI physics discipline lead

His search quickly narrowed to downhole applications — using geophysical instruments to collect data about surrounding soil and rock media. Geophysical instruments used for boreholes typically consist of miniaturized sensors and electronic systems contained in a rugged package.

Hertzog also identified potential techniques, of which several cutting-edge nuclear assessment techniques appear especially promising. "We know some techniques, such as prompt fission neutron assay and neutron-gamma, can be refined to get quantitative data," said Hertzog, "but they will need to be adapted for mapping subsurface contamination."

Because the prompt fission neutron (PFN) technique is particularly appropriate for actinides, the INEEL has begun developing a PFN instrument (see photo right) for downhole applications. It uses a 100- to 120-kilovolt linear accelerator in a sealed tube to generate a short burst of fast neutrons. With energies in the range of 14 million electron volts, the neutrons penetrate the soil and rock surrounding the borehole. The neutrons are slowed

Researchers at the INEEL have modified a prompt fission neutron instrument (left) for downhole applications. As seen, adapting instruments for downhole applications often requires modifying them into slim and rugged packages so they can fit inside well casings.

down, thermalized and eventually captured by the surrounding atoms. If the capturing atoms are fissile, they split spontaneously and produce additional neutrons. A shielded detector counts these neutrons. The count provides a means of accurately determining the amount of fissile elements present in the soil because it is related to their concentrations.

PFN technology also provides a nearly continuous profile of contaminant concentrations as a function of the instrument's position in the borehole. Using this information, researchers can develop a three-dimensional map of actinide concentrations. However, because the instrument's resolution is determined by the absorption of neutrons, the potential 'view' is limited to an area within 50 centimeters of the borehole and is dependent on the area's moisture content.

> ***"...our goal is to refine the instrument's sensitivity so we can confidently define those areas where actinides are within regulatory limits and those areas requiring some type of remedial action."***
>
> *— R. Hertzog, SSI physics discipline lead*

Hertzog believes PFN technology has other potential uses, such as monitoring changes in fissile material concentrations, and measuring and monitoring porosity and moisture in soil and rock media.

"Right now, our goal is to refine the instrument's sensitivity so we can confidently define those areas where actinides are within regulatory limits and those areas requiring some type of remedial action," said Hertzog. "Since 10 nanocuries per gram is an accepted level for buried low-level waste, we need an instrument with corresponding sensitivity."

Hertzog believes combining neutron and neutron-gamma probes offers even greater possibilities for quantifying subsurface contamination.

(Quantitative geophysics continued on page 6)

The INEEL's Subsurface Neutron Interrogation Facility

Hertzog and several collaborators designed and built a facility at the INEEL — the Subsurface Neutron Interrogation Facility — to develop, test and calibrate nondestructive assay techniques. The new facility is a gravel-filled tank that is 17 feet long by 10 feet wide by 17 feet deep. In the gravel matrix are two pits, which can be filled with a variety of rock and soil media and be maintained with both wet and dry conditions.

Because the facility permits the simulation of a downhole environment, researchers plan to use it to refine geophysical instruments so they are both sensitive enough and applicable for subsurface contamination. Prompt gamma neutron activation analysis and passive gamma-ray spectrometry are the first techniques to be tested.

"Now that we have the instruments and facilities to conduct research, we can begin quantifying chlorinated solvents in the region of the borehole," said Hertzog. "The next step will be to begin quantifying the mineral associations."

A view of the INEEL's Subsurface Neutron Interrogation Facility (left) shows the two pits and surrounding gravel matrix used to test geophysical instruments. Sources, targets and surrogates representing contaminants of interest can be placed in either media in the pits or inserted into ports (shown in the drawing above).

(Quantitative geophysics continued from page 5)

Traditional neutron probes can detect the presence of water and hydrocarbons through the presence of hydrogen, and passive gamma probes can detect the presence of radioactive isotopes that emit gamma radiation, such as cesium.

Hertzog plans to explore these options as well as new nondestructive assay techniques, such as prompt gamma neutron activation analysis (PGNAA). PGNAA, like PFN, also uses neutron bombardment. However, it uses two processes — inelastic neutron scattering and thermal neutron capture — to excite nuclei to produce gamma-ray emissions, which are then used to provide information about the concentrations of radioactive isotopes present. The gamma-ray emissions are essentially 'signatures' of constituent elements. Their intensity provides quantitative information.

"There is a definite need for quantitative techniques. Though the research scope needed to address DOE's environmental contamination is significantly larger than for many industries, that is the challenge we have set for ourselves."

— R. Hertzog, SSI physics discipline lead

"There is a definite need for quantitative techniques," said Hertzog. "Though the scope of research needed to address DOE's environmental contamination is significantly larger than it is for many industries, that is the challenge we have set for ourselves."

Note: This research was funded by the INEEL's Environmental Systems Research and Analysis (ESRA) program.

Contact: Russel Hertzog
(208) 526-4092
hertr@inel.gov

The Science of Borehole Geophysics

Geologists learn a great deal from drilling holes and taking cores and samples. But drilling into areas that are known to be contaminated can be expensive and the results are not always representative of broader geological conditions.

To a geophysicist, the hole remaining after drilling offers as much opportunity to learn about the subsurface as the drilling and sampling itself. Though traditional geophysical exploration is associated with sophisticated airborne and ground-based measurements, borehole geophysics is a subdiscipline that uses measurements gathered from instruments lowered into wells. The data that is gathered can be used to interpret the type of rock, detect the presence of minerals and fluids, and characterize the pore space environment.

Borehole geophysical techniques use various methods — nuclear, electrical, electromagnetic, seismic, gravity and magnetic — to collect measurements. Techniques based on nuclear methods can be used inside steel drill pipe or casing. Most electrical, electromagnetic and seismic methods are used in an open hole and in hole-to-hole configurations to study the rocks between adjacent boreholes. Surface-to-borehole and borehole-to-surface measurements are used to increase the radius of investigation around the borehole.

Workers at the INEEL prepare a borehole instrument that will be used to gather subsurface contamination data at the INEEL's Radioactive Waste Management Complex Subsurface Disposal Area. The activity is part of an ongoing environmental investigation to identify remedial alternatives for the contamination.

Register online at www.mtgs-etc.com/inra.htm

2nd Annual Subsurface Science Symposium

2001 Subsurface Science Symposium

The upcoming 2nd Annual Subsurface Science Symposium, jointly sponsored by Inland Northwest Research Alliance (INRA) and the INEEL, is expected to be even more popular than last year's symposium. Not only will it exhibit a variety of subsurface science research projects being conducted at the INEEL and through INRA, it will feature presentations by some of the most respected names in the field — scientists from Stanford University, Rice University, Northeastern University, the University of Stuttgart and several DOE national laboratories.

"When I was asked to assist in recruiting speakers, I decided to seek out the field's top researchers," said Russ Hertzog, SSI physics discipline lead and one of the symposium's organizers. He looked for talent outside the INEEL and INRA to maximize the amount of dialogue and sharing. "We know that to achieve the greatest success, the broader research community must be included in what we are doing," said Hertzog.

This year, one of the symposium's purposes is to further develop a common framework for what constitutes mesoscale research. While the INEEL and its associated researchers have established a working definition for mesoscale — the scale where coupling of phenomena occur — there isn't a universal definition. The symposium's organizers hope that presenting and discussing example research projects will help establish this.

"Mesoscale research projects are large and expensive, so we must be diligent in designing experiments to answer meaningful multidisciplinary questions and appropriately handle the scaling issues," said Hertzog. "At the same time, we need to keep in mind that this is basic research. The null hypothesis must be tested as well."

Hertzog said the SSI's challenge is integrating and scaling environmental research. He used the oil and gas industry and the field of petrophysics as an example of integrating laboratory-scale research to field-scale problems.

"We hope this symposium will foster the type of cross-discipline dialogue we need to address scaling issues and create reasonable mathematical models of subsurface processes," said Hertzog.

The symposium offers other opportunities besides creating a forum for discussing the technical aspects of subsurface science research. Sessions are planned for discussing technology transfer, environmental policy and the Subsurface Science Research Institute, the first multi-institutional doctoral program for subsurface science.

"Last year, we planned for about 50 participants and more than 140 came," said Gautam Pillay, INRA Executive Director. "This year, we're capitalizing on last year's interest and planning a larger symposium."

Online registration is available at www.mtgs-etc.com/inra.htm

Keynote Speaker

- *Dr. Steve Wells, Director, Desert Research Institute*

Plenary Speakers

- *Dr. Gautam Pillay, Executive Director, INRA*
- *Dr. P. Michael Wright, Director, Subsurface Science Initiative, INEEL*
- *Dr. Carey Rappaport, Associate Director, Center for Subsurface Sensing and Imaging, Northeastern University*
- *Dr. Hans-Peter Koschitzky, Technical Director, Research Facility for Subsurface Remediation, University of Stuttgart*

Concurrent Sessions/Lead Speakers

- *Geochemistry – Sue Clark, Washington State University*
- *Geophysics – Rosemary Knight, Stanford University*
- *Hydrology – Earl Mattson, INEEL*
- *Flow and Transport – Tissa Illangasekare, Colorado School of Mines*
- *Bioremediation – Terry Hazen, Lawrence Berkeley National Laboratory*
- *Remediation Science and Technology – Ron Sims, Utah State University*
- *Modeling – Don Morton, University of Montana*
- *Scaling – Roger Beckie, University of British Columbia*
- *Environmental Policy and Management – J. D. Wulfhorst, University of Idaho*
- *INRA Subsurface Science Research Institute – Jack Pelton, Boise State University*
- *Technology Transfer – Will Swearingen, Montana State University*

(INEEL wins continued from page 1)

Research and Development (LDRD) resources and $12 million in Environmental Systems Research and Analysis (ESRA) funding.

"The EMSP awards validate the SSI's research efforts and augment our own internal investments," said Wright. "These awards mean that we will be able to move ahead more quickly with research in this critical area."

Mike McIlwain, the INEEL's EMSP proposal coordinator, believes the INEEL's focus on subsurface science and the SSI's successful recruitment efforts also contributed to the increased number of awards. "A researcher's reputation and number of peer-reviewed publications weighs heavily when proposals are evaluated," said McIlwain. "We use the same criteria in recruiting, and the SSI's newest recruits won many of this year's awards."

> *"The number of awards we received clearly indicates our subsurface science program is on the right track."*
>
> — M. McIlwain, INEEL EMSP proposal coordinator

The number of awards reflect the development of INEEL's successful partnerships with respected research universities, such as the Massachusetts Institute of Technology, Stanford University, Carnegie Mellon and the University of Oslo. Seven awards also involve collaborative research with Inland Northwest Research Alliance (INRA) universities.

"The number of awards we received clearly indicates our subsurface science program is on the right track," said McIlwain.

Contact: Mike McIlwain
(208) 526-8130
mem@inel.gov

EMSP Project Summaries

Ten research projects related to subsurface contamination in the vadose and saturated zone were recently awarded funding by DOE's Office of Science Environmental Management Science Program (EMSP). Seven projects will be led by researchers at the INEEL; three other projects will be conducted in collaboration with INEEL researchers.

Multiphase Flow in Complex Fracture Apertures Under a Wide Range of Flow Conditions

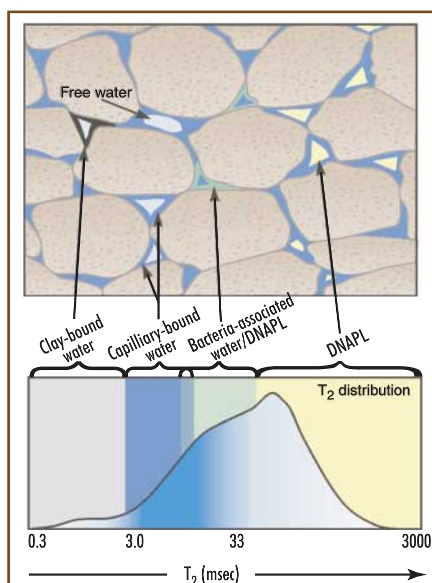
This project will develop new conceptual models to understand how pollutants travel in the vadose zone. Researchers will study multiphase flow in complex fracture apertures using a coordinated experimental and computer modeling program well suited to geometrically complex boundary conditions. The project will test the hypothesis that focused flow on preferred pathways (such as fracture apertures), intermittent flow conditions, and the colloid-mediated transport of strongly adsorbed pollutants play important roles in rapidly transporting subsurface contamination. Fractal and nonfractal fracture aperture models will be used in both the computer simulations and the experiments. The experiments will be conducted at the INEEL's Matched Index-of-Refraction (MIR) Flow System facility.

Principal Investigator: P. Meakin (INEEL)
Collaborators: G. McCreery, D. McEligot (INEEL); D. Rothman (Massachusetts Institute of Technology); B. Jarntveit, J. Feder (University of Oslo)

Resolving the Impact of Biological Processes on DNAPL Transport in Unsaturated Porous Media through Nuclear Magnetic Resonance Relaxation Time Measurements

This project will investigate the capabilities and limitations of low-field nuclear magnetic resonance (NMR) relaxation decay rate measurements for determining environmental properties affecting dense nonaqueous phase liquids (DNAPL) solvent flow in the subsurface. The oil and gas industry uses NMR measurements in deep subsurface formations to determine porosity and hydrocarbon content, and to estimate formation permeability. These

INEEL researchers and their collaborators will study how downhole nuclear magnetic resonance (NMR) relaxation decay rate measurements (illustrated below) can be used to better understand the biotic and abiotic factors that influence the behavior of dense nonaqueous phase liquids (DNAPLs) in pore spaces of subsurface media. DNAPL transport is an area of concern for DOE sites with subsurface organic solvent contamination.



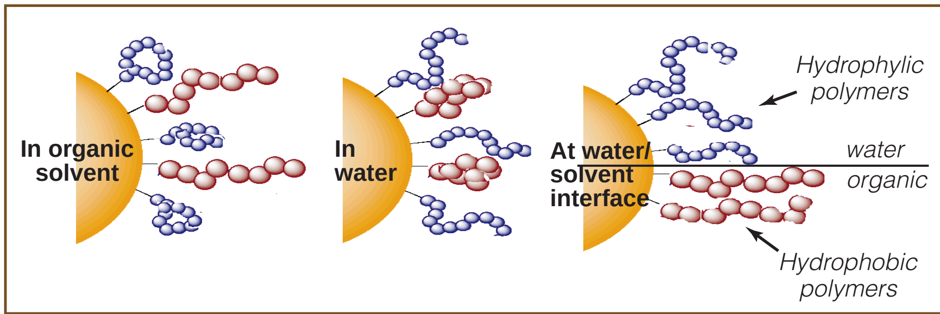
determinations rely on NMR's ability to distinguish between water and hydrocarbons in the pore space and to obtain the pore size distributions from relaxation decay rate distributions. Using systematic laboratory experiments, the team will extend and adapt this capability to characterize near-surface environmental problems.

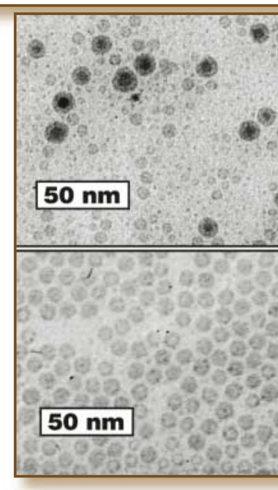
Principal Investigator: R. Hertzog (INEEL)
Collaborators: G. Geesey, T. White (INEEL); C. Straley (Schlumberger-Doll Research Center); T. Bryar (Stanford University); J. Seymour (Montana State University); C. Ho (Sandia National Laboratories)

Long-term Stewardship of Mixed Wastes: Passive Reactive Barriers for Simultaneous In Situ Remediation of Chlorinated Solvent, Heavy Metal, and Radionuclide Contaminants

This project will investigate in situ halocarbon degradation and simultaneous radionuclide/heavy metal immobilization in groundwater using passive reactive barriers (PRBs) formed with *Cellulomonas* organisms. The organisms can catalyze metal reduction (e.g., iron, chromium, uranium) resulting in radionuclide immobilization and halocarbon degradation. These reactions can be stimulated using inexpensive carbon sources and reduction will continue after the carbon source is depleted. The team will experiment with a wide spectrum of electron donors, acceptors and substrates to define optimal strategies for establishment and control of sessile *Cellulomonas* communities to form effective PRBs.

Principal Investigator: W. Apel (INEEL)
Collaborators: R. Gerlach (Montana State University); B. Peyton (Washington State University)





An INEEL-led project was awarded funding to examine the potential use of engineered nanoparticles for remediating organic solvents. The research project will examine the potential of using specific nanoparticles for remediating contamination at the nonaqueous phase liquids (NAPL)-water interface. An illustration (above) shows how hydrophilic and hydrophobic polymers respond in water and solvent solutions and at the water/solvent interface. Two photomicrographs show two of the nanoparticles that will be studied — palladium-coated iron (middle right) and surfactant-coated iron (Fe(0)) (bottom right).

Transport, Targeting, and Applications of Functional Nanoparticles for Degradation of Chlorinated Organic Solvents

This project will evaluate the feasibility of using reactive nanoparticles engineered for subsurface remediation tasks. The project will focus on degrading a nonaqueous phase liquid chlorinated solvent. The team will synthesize and test the ability of composite nanoparticles (consisting of iron metal and a noble metal catalyst) to degrade trichoroethylene suspended in water. The nanoparticle surfaces will then be modified with polymer coatings and tested for their ability to migrate through porous media and selectively partition at the nonaqueous phase liquids (NAPL)-water interface, a primary challenge. The particle mobility, targeting capabilities and solvent degradation rates will be tested at several scales to demonstrate the specific application and to develop an improved transport model for colloids. This represents an initial step toward understanding how to manipulate colloid mobility and incorporate colloids into a variety of subsurface remediation strategies.

Principal Investigator: G. Redden (INEEL)
Collaborators: P. Meakin, H. Rollins, D. Ginosar (INEEL); G. Lowry, R. Tilton, S. Majetich, D. Scholl, K. Matyjaszewski (Carnegie Mellon University)

Coupling of Realistic Rate Estimates with Genomics for Assessing Contaminant Attenuation and Long-Term Plume Containment

This project will validate the process and rate of degradation of dissolved trichloroethylene (TCE) through natural attenuation. Two hypotheses will be tested: 1) Realistic values for in situ rates of TCE cometabolism can be obtained by

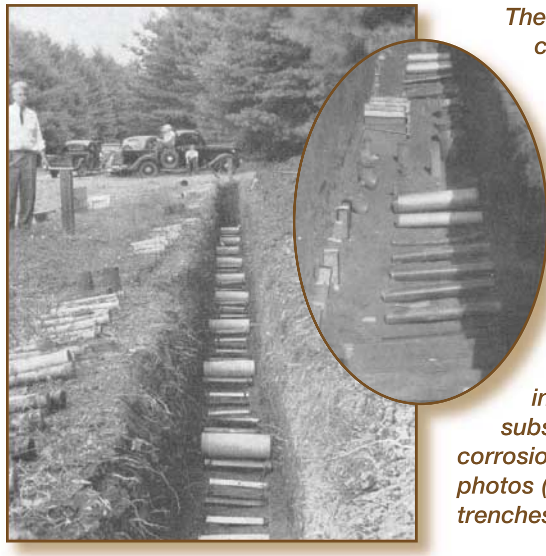
(EMSP awards continued on page 10)

(EMSP awards continued from page 9)

sustaining microorganisms at the low catabolic activities consistent with aquifer conditions; 2) Patterns of functional gene expression evident in these communities under starvation conditions while carrying out TCE cometabolism can be used to diagnose the activity in an aquifer. Using rate parameters derived in low-growth bioreactors, the team will complete models to predict the amount of time it will take to attain background TCE levels in a contaminated aquifer.
Principal Investigator: F. Colwell (INEEL)
Collaborators: R. Crawford (University of Idaho); K. Sorensen (North Wind Environmental, Inc.)

Coupled Flow and Reactivity in Variably Saturated Porous Media

This project will use the INEEL's two-meter geotechnical centrifuge to develop new experimental approaches for describing contaminant adsorption and transport in heterogeneous, variably saturated media (i.e., the vadose zone). A hypothesis will be examined: Reactivity of variably saturated porous media depends on the moisture content of the media and can be represented by a relatively simple function applicable over a range of scales, contaminants and media. The belief is that this simple function is dependent primarily on media characteristics, rather than contaminant chemistry. Support of the hypothesis would allow contaminant reactivity to be derived from laboratory and field tracer experiments using environmentally benign tracers.
Principal Investigator: C. Palmer (INEEL)
Collaborators: E. Mattson (INEEL); R. Smith (University of Idaho)



The INEEL and numerous collaborators will use an interdisciplinary approach to examine various metal specimens buried 32 years ago by the National Institute of Standards and Technology (NIST). The results of the project, funded by the DOE's Environmental Management Science Program, will help DOE better understand the effects of long-term burial on metal integrity, and the complex subsurface processes affecting corrosion and degradation. The historic photos (left) show specimen-filled trenches prior to burial.

Underground Corrosion after 32 Years: A Study of Fate and Transport

In 1970, the National Institute of Standards and Technology (NIST) buried 6,324 specimens — including stainless steel types, specialty alloys and composite configurations — at six diverse soil sites throughout the country. Of these, more than 190 specimens remain undisturbed at each site.

An interdisciplinary approach will be used to examine the soil and environment surrounding the specimens. The results will be used to correlate the complex interrelations between metal integrity, corrosion rates, corrosion mechanisms, soil properties, soil microbiology, plant and animal interaction with corrosion products, and fate and transport of metallic ions results to better understand corrosion, underground material degradation and the behavior of corrosion products.
Principal Investigator: K. Adler Flitton (INEEL)
Collaborators: L. Zirker, R. Rogers, S. Alessi, C. Bishop, G. Groenewold, M. Leesender, P. Nagata (INEEL); Diversa Corporation; GoldSim Consulting Group; E. Escalante (private); M. Louthan (Savannah River Technology Center); M. Knoll (Boise State University); NIST; J. Lippold (Ohio State University)

Field-scale In Situ Measurements of Vadose Zone Flow and Transport Using Multiple Tracers at the INEEL's Vadose Zone Research Park

This project, led by the Los Alamos National Laboratories, is aimed at better understanding field scale vadose zone flow and transport processes, and establishing defensible links between laboratory- and field-derived transport parameters for conservative and reactive elements in the vadose zone. The research will be conducted at the INEEL's Vadose Zone Research Park, which has a three-dimensional instrumentation array strategically surrounding a new infiltration pond. The effects of fluid flux, water chemistry, and degree of saturation on contaminant transport in the vadose zone will be studied as the infiltration pond is filled, as will the physical and chemical interactions between the vadose and saturated zones. The research will include examining the effects of the flow of the neighboring Big Lost River.

Principal Investigator: R. Roback (Los Alamos National Laboratory)
Collaborators: L. Hull (INEEL); Y. Asmerom (University of New Mexico)

Advanced Conceptual Models for Unsaturated and Two-Phase Flow in Fractured Rock

This project, led by the University of Idaho, will focus on understanding phase structure, which is critical to understanding contaminant migration. Two-phase flow creates complex phase structures that control contaminant transport within phases (e.g., solutes and gases) and interphase mass transport (e.g., evaporation/ volatilization and DNAPL dissolution). The dramatic contrast between the properties of fractures and the surrounding porous matrix can result in extremely complex phase structures within the fracture network. These phase structures may facilitate rapid transport and widespread distribution of concentrated contamination but are difficult to describe using current conceptual models.

Principal Investigator: M. Nicholl (University of Idaho)
Collaborators: T. Wood (INEEL); R. Glass (Sandia National Laboratories); H. Rajaram (University of Colorado)

Calcite Precipitation and Trace Metal Partitioning in Groundwater and the Vadose Zone: Remediation of Strontium-90 and Other Divalent Metals and Radionuclides in Arid Western Environments

This project, led by the University of Idaho, will focus on developing a better understanding of the coupling of calcite precipitation and trace metal partitioning in subsurface environments. Calcite can incorporate metals such as strontium, cadmium, lead, and cobalt into its crystal structure, potentially leading to long-term sequestration. This research seeks to define the mechanisms and rates of microbially-facilitated calcite precipitation by naturally-occurring urea-hydrolyzing organisms in the subsurface. Laboratory and field scale experiments involve introducing urea and nutrients to stimulate microbial growth in a natural aquifer and vadose zone perched water body. The degradation products of urea are expected to cause calcite precipitation and sequestering of groundwater metal contaminants. Indicators of biogeochemical conditions conducive to manipulation for enhanced calcite precipitation will be identified. This research, if successful, will lead to more effective remediation technologies for subsurface sites contaminated by metals and radionuclides.

Principal Investigator: R. Smith (University of Idaho)
Collaborators: Y. Fujita (INEEL); G. Ferris (University of Toronto)

(Western connections continued from page 3)

Of the various environmental issues heard on the tour, one of the most geographically broad and challenging is mining-related zinc and cadmium contamination, which particularly affects the Coeur d'Alene basin of Idaho and Washington. One of Western Connections' first actions was to address this issue. They helped organize a multi-institutional symposium, held in September 2002, which included various INEEL and university researchers; federal, state and tribal organizations; and political leaders. (See box on page 3.)

"The technical problem is beyond the scope of any single agency or organization," said Paul Wichlacz, an INEEL researcher and co-chair of the symposium's technical program. "But, collectively, we can define what research is needed and begin working together to find solutions."

The Western Connections team expects to remain busy. "We have discovered plenty of problems that lend themselves to our approach," said Brown. "Our challenge is to keep the dialogue open and find ways to work together successfully. It is up to us to demonstrate the INEEL's value to the region."

More information about Western Connections is available online at http://www.inel.gov/western-connections/

Contact: Jan Brown
(208) 526-4342
browjm@inel.gov

New Journal for Vadose Zone Research

A new publication dedicated to vadose zone research — the Vadose Zone Journal — has been launched by the Soil Science Society of America (SSSA). The online peer-reviewed journal fills a void in scientific publication.

"Before this journal existed, soil physicists working outside of the field of agronomy had a limited range of opportunities to publish their research on environmental contamination," said Robert Lenhard, SSI hydrology discipline lead. "Our options were often limited to the *Journal of Contaminant Hydrology* or the *Water Resources Research*. Having a topical journal within the SSSA is a great service to the field of vadose zone research."

The objective of the new journal is to share information that supports science-based decision-making and sustainable management of the vadose zone. The new journal's editor, Martinus (Rien) Th. van Genuchten, described why this is important. "Many industrial, municipal and engineering activities are now also known to impact the vadose zone, and hence, indirectly, all of the subsurface environment," said van Genuchten. "As a result, many state and federal agencies … are increasingly addressing vadose zone issues, including serving as funding agencies for vadose zone investigations."

The journal will address a wide variety of technical topics, such as biogeochemical transformation; microbial, multiphase and variable saturation flow processes; contaminant fate and transport; design and performance of waste disposal facilities; and bioremediation. It will also include assessment and policy analyses and discussions of broader issues, such as water table management, regional and global climate change impacts on the vadose zone, carbon sequestration, and the long-term stewardship of contaminated sites in the vadose zone.

Most importantly for the SSI, the journal will cover unresolved issues, such as technologies for three-dimensional mapping of subsurface heterogeneities and contaminants; and the coupling of physical, chemical and biological processes at all scales.

Though the broad importance of vadose zone issues will help ensure the journal's success, the publisher plans to improve its chances by conducting the entire review and publication process online — from manuscript submissions through final publication. "Electronic publication offers numerous advantages," said Lenhard, who was recruited as an associate editor six months ago. "The cycle time for receiving and reviewing articles is accelerated, and there will be fewer limitations on color photos or illustrations. This will not reduce the time consumed by peer review, but I expect the quality of the published work will help the journal survive."

For a subscription, information about upcoming original research papers and reviews, and details about submitting manuscripts, visit http://www.vadosezonejournal.org/ A free introductory subscription is available through December 2002.

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